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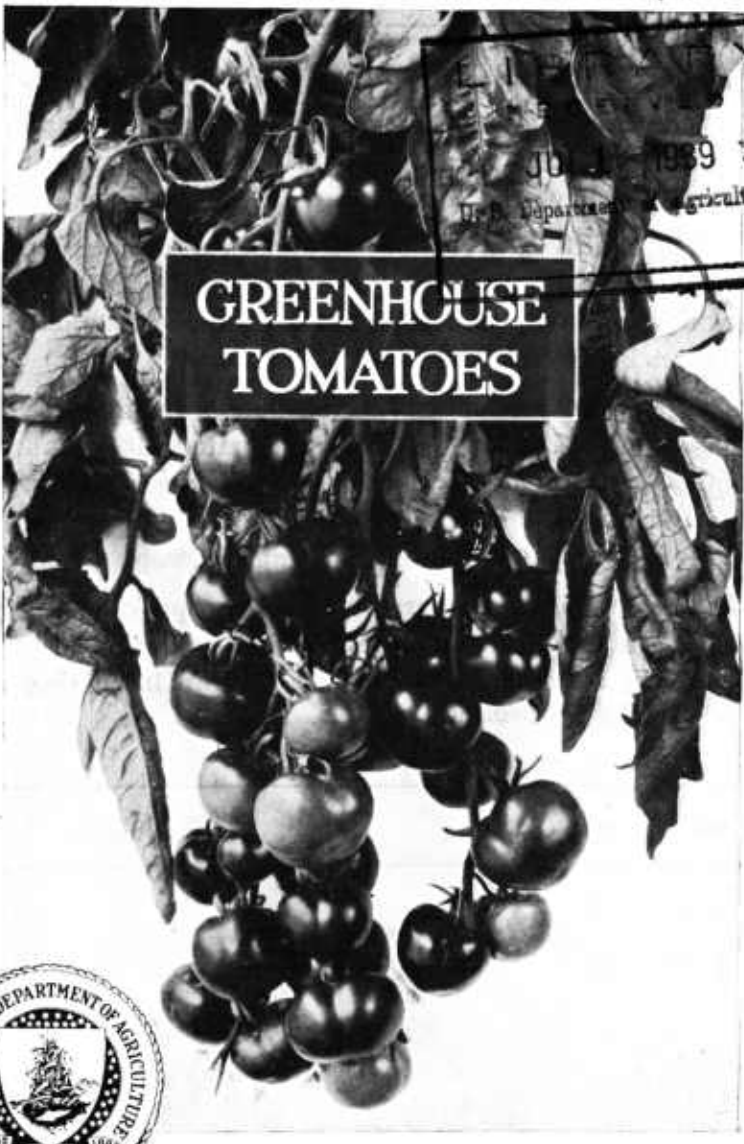
GREENHOUSE TOMATOES



TOMATOES GROWN IN GREENHOUSES near the markets can be ripened on the plants and put into the consumers' hands within a few hours of the time they are picked.

The quality of greenhouse tomatoes is far superior to that of the outdoor-grown crop competing with it, which is usually picked green and shipped long distances before reaching the markets.

Successful production in greenhouses requires the use of suitable structures with adequate heating and other equipment, good seed of suitable varieties, fertile well-adapted soil, and painstaking care in growing the plants and in handling the crop.

The greenhouse operator who can provide the high-grade equipment necessary and give the crop the care it demands is likely to find an increasing market for his product.

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GREENHOUSE TOMATOES

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INTRODUCTION

THE COMMERCIAL PRODUCTION of tomatoes in greenhouses in the United States is a development of the last third of a century. Previous to about 1900 little attention was paid to the forcing of the crop in glasshouses, the present importance of which is a marked tribute to the excellence of the product and the success of vegetable-greenhouse men in working out methods for handling this, the most difficult of the important vegetable forcing crops. Lettuce, cucumbers, and tomatoes constitute perhaps 90 per cent of the products of the vegetable-forcing ranges throughout the United States. Some ranges devote their energies to lettuce and cucumbers, but most of them grow tomatoes at some time during the year.

The bulk of the vegetable crops grown in greenhouses is produced in the New England, Middle Atlantic, East North Central, and West North Central States. Climatic conditions largely account for the absence of the industry in the South Atlantic, Gulf Coast, and Southwestern States, where it is usually possible to produce a long list of fresh vegetables as outdoor crops over the greater part of the year, and these sections also are accessible to tropical centers where year-round production of certain vegetables is possible.

Greenhouse ranges devoted to the tomato crop are to be found throughout the States where the industry has attained its greatest importance. Arlington, Mass., and Grand Rapids, Mich., are the two oldest important forcing centers. Large greenhouse ranges are to be found around Rochester, N. Y.; Philadelphia, Pa.; Ashtabula,

Cleveland, Toledo, and Columbus, Ohio; Chicago, Ill.; and other points. Suitable soil, ample labor, cheap fuel, and good transportation facilities have been contributing factors in the development of the industry in many sections.

When ripened on the vine, greenhouse tomatoes are far superior in quality to those grown outdoors in warm sections under conditions making it necessary to pick the fruit green in order to get it into the hands of the distant consumer without undue loss. Tomatoes marketed during the winter and early spring months when prices are high are usually served as a salad or as an ingredient of a salad. A comparatively small quantity is ample for several persons; hence the vegetable is as economical to the housewife as other available salad materials.

The greenhouse owner must make a large investment in houses and equipment, and he must be prepared to spend large sums for the maintenance of conditions suitable for this exacting crop. On the other hand, a grower of field tomatoes 2,000 or more miles from the markets must spend large sums for picking, packing, transportation, and handling before his crop can be realized upon. The products of properly located greenhouse ranges where fuel, labor, and other essentials can be obtained economically are usually able to compete successfully with tomatoes grown at distant points out of doors. The vegetable-forcing industry is of importance, and the tomato is receiving its full share of attention.

GREENHOUSES

A forcing house for tomatoes must be suitable for the exacting requirements of the crop. It must be of such construction that the least possible interference is offered to the entrance of light. It must be fitted with a ventilating system that permits the changing of the air without drafts, and it must have a heating system capable of maintaining a sufficiently high and uniform temperature. A house containing a large volume of air is usually less subject to sudden fluctuations in temperature than a small house. Moreover, a high house with the ventilators several feet above the plants usually makes it possible to ventilate without drafts striking the plants. The house must have sufficient headroom for the plants, but structures meeting the other important requirements usually have an abundance of such room for tomatoes.

Detached houses 60 to 80 feet wide and 500 to 600 feet long (fig. 1) are largely used. The ridge-and-furrow type, with high gutters, is widely used for tomatoes. These houses are built in widths up to about 40 feet without inside posts, a steel truss supporting the roof in the wider ones. Three of these houses may be made to inclose a space of 100 feet or more in width having only two outside walls, two inside gutters, and two rows of inside posts, each row being directly beneath and supporting a gutter. The inside gutters cast some shade on the crop, but if they are sufficiently high this objection is negligible. The present tendency is toward large houses with high side walls of sash-bar and glass construction and with roofs so high that the glass is at a considerable distance from the plants.

BENCHES COMPARED WITH GROUND BEDS

During the early days of the industry practically all tomato growers believed that raised benches and bottom heat were essential to success with the crop. (Fig. 2.) It was soon found that good crops of tomatoes could be produced in houses without raised benches where the space was treated as an inclosed area to be handled in much the same manner as intensively conducted outdoor operations. Benches are still used to a limited extent in tomato houses, but in houses of newer construction there is a growing tendency to dispense with them.

Many growers believe that tomatoes grown on benches require several days less time to come into bearing than those planted in ground beds. Bottom heat from pipes located under the benches, better aeration of the soil on the benches, and better drainage all contribute to the earliness of the bench crop. Provision for adequate

FIGURE 1.—A large greenhouse devoted to a crop of tomatoes. The plants are trained to slender stakes set in the ground near them and supported by wires attached to the frame of the structure

drainage, care in watering, and the use of temporary heating lines laid on the surface of the soil during the early stages of growth make it possible to secure earliness equal to that of the crop planted in ground beds. Benches are very expensive, and the cost of maintenance is often high. They bring the plants near the glass, where they are more subject to fluctuations in temperature and more difficult to cultivate, trim, and train. Moreover, the tomatoes are difficult to gather when grown on raised benches. Under present methods of culture the ground beds are often plowed with a team or a tractor, and the cost of applying the manure and preparing the soil is much less than when the work is done by hand on raised benches. The thin layer of soil usually employed on raised benches must, as a rule, be changed every year, but with ground benches such a procedure can usually be avoided. The ideal tomato house is a small field under glass where temperature, moisture, and other suitable growing conditions can be maintained. (Fig. 3.)

FIGURE 2.—Greenhouse tomatoes on raised benches. The plants are trimmed to a single stem and trained to strings tied to the roof of the greenhouse

FIGURE 3.—Tomatoes growing in a house where the plants are set and handled in much the same manner as where the crop is grown intensively outdoors. The concrete curbs are used to keep the soil out of the cinder walks

WALKS

Walks in greenhouses occupy space involved in heat and maintenance costs, and only those absolutely necessary to the management of the houses should be installed. Concrete walks are desirable from the standpoint of convenience, chiefly because they serve as tracks for wheelbarrows or trucks used in growing and harvesting the crop. It has been found that the control of nematodes is made more difficult by permanent walks in the greenhouse, as these pests penetrate under walks and side walls where they can not be reached by most methods of soil treatment. There seems to be a growing tendency to use boards laid between the rows as temporary walks and to avoid concrete or other permanent installations. Figure 1 shows the interior of a large house with concrete walks along each side. This is a good arrangement, as the tomato plants can not be set near the heating pipes where they would be subjected to excessive heat. This plan also has the advantage that it leaves the interior of the house practically free of obstructions which would otherwise interfere with plowing and other cultural operations.

HEATING

The heating system employed must be capable of maintaining a uniform temperature, as sudden fluctuations are very injurious to the crop. A gradual change from about 60° F. at night to 70° to 85° during the day is permissible, but frequent fluctuations either day or night will usually prove harmful to the crop. The hot-water system, using either forced or gravity circulation, and vacuum and low-pressure steam systems give good results. Gravity-circulation hot-water systems are well suited to houses of moderate size. The rate of circulation is slow, necessitating the use of more radiation than is needed with certain forced-circulation or steam systems. Moreover, this type of system is not particularly adapted for use in very large houses. In small establishments, where the care that can be given the boiler is usually limited, hot water is especially suitable, as the large volume of water in the system cools slowly, making frequent attention unnecessary. Forced-circulation hot-water systems are in satisfactory use in many houses. A pump of suitable type is used to hasten circulation, and in some cases the system is so arranged that entire dependence is placed on the pump for circulating the water. Vacuum and low-pressure systems require less radiation than is necessary for hot-water systems. They are very satisfactory, being particularly adapted to large houses and to ranges where the boilers have regular attention.

The size and arrangement of the piping in a tomato greenhouse are determined by the kind of heating system employed and by the size and construction of the house. Although overhead piping casts some shade on the developing crop, it is generally believed that at least a part of the radiation should be overhead, as pipes so located temper the air entering through the top ventilators and prevent cold drafts from striking the plants. (See fig. 1.) For the same reason it is desirable that part of the radiation be placed on the side walls. The current of warm air rising from pipes so placed prevents cold air entering through the walls and roof from striking the plants.

The crop is safely blanketed under a canopy of warm air through which cold drafts are not liable to penetrate. The gable ends of large houses are usually supplied with banks of pipe to cut off the cold air from these large exposed surfaces.

Hot-water or steam heating systems can readily be adapted to such an arrangement of the pipes. The flow pipes are usually placed overhead at a higher level than the coils, with the whole system graded so that it slopes gradually downward to the boiler. With narrow ridge-and-furrow houses the radiation pipes are usually placed on the posts supporting the gutters, but in wider houses of this type at least a part of the radiation is placed overhead.

Table 1 shows the radiation needed to maintain temperatures suitable for tomatoes.

TABLE 1.—*Temperatures to be maintained and length of pipe of different sizes needed to supply radiation for gravity-circulation hot-water systems at a minimum outdoor temperature of 0° F.*

Temperature to be maintained	Radiation for each 1,000 square feet of glass or its equivalent [1]	Length of pipe required to supply this radiation		
		1¼-inch size	1½-inch size	2-inch size
	Square feet	*Feet*	*Feet*	*Feet*
60° F	401	920	801	641
65° F	460	1,057	921	737
70° F	583	1,339	1,166	933

[1] By the term "equivalent" is meant the side walls of wood or masonry construction; 4 square feet of exposed surface of this character is figured as needing the same radiation as 1 square foot of exposed glass surface.

The exact amount of radiation to be installed can be determined only after giving consideration to such factors as geographical location, tightness of houses, exposure, and efficiency of the heating plant. In sections where low temperatures prevail or occur at intervals it is necessary to install more radiation than that shown in the table. The figures given are for an outside temperature of 0° F. Where lower temperatures occur the amount of radiation should be increased at least 1 per cent for each degree below zero. Thus, in sections where the temperature occasionally falls to −20°, 20 per cent more radiation should be installed. Greenhouses in very exposed positions should have additional radiation, especially on the side from which the prevailing winds come.

VENTILATORS

Greenhouses for tomato growing usually have ventilators along the sides just below the eaves and along both sides of the ridge. Side ventilators are often hinged just below the eaves and operated by machines attached to the side posts of the structure. Top ventilators are generally hinged to a member just under the ridge cap. Unless they are opened very wide, such an arrangement allows water to drop from the ventilators to the roof. The overhanging ridge cap makes a water-tight joint. Figure 9 of Farmers' Bulletin 1318

shows the details of this construction. Machines for operating the top ventilators are placed on posts or pedestals at suitable intervals and within easy reach of the operator. Extreme care in securing tight-fitting easy-operating ventilators prevents drafts and aids materially in obtaining good crops.

WATER SYSTEMS

Water pipes are usually placed underground and fitted with enough faucets so that any part of the house can be reached with 50 to 75 feet of hose. When the application of water is to be made entirely with a hose no additional equipment is necessary.

Subirrigation systems composed of lines of tile spaced from 2 to 4 feet apart and buried in the soil sufficiently to be out of the way of tillage tools make it possible to water the crop without packing the surface or wetting the foliage. The size of the tile, the distance between the rows, and the depth the tile is buried are determined largely by the character of the soil. Very tenacious or impervious soils, where the lateral movement of the water is slow, require the installation of lines of tile nearer together than is necessary with lighter soils. The lines of tile are provided with openings every 100 to 150 feet, so that the end of a hose can be inserted; and the water is run into the tiles until they are filled or the soil sufficiently moistened, when the hose is moved to the next line. This system insures against overwatering, as the lines of tile serve as drains also, and much benefit is secured by the aeration of the soil. Greenhouse-vegetable growers could well devote more attention to the subirrigation method of applying water.

Overhead sprinkler systems are extensively employed during the early stages of the crop, or until about the time that the blossoms appear; but they have not met with much favor for growing tomatoes, because wetting the foliage creates greenhouse conditions favorable to the development of certain diseases and unfavorable for the ripening and transfer of pollen.

CROPPING PLANS

Tomatoes are seldom grown as a midwinter greenhouse crop. They are usually produced during the fall and early winter or as a spring crop. Few vegetable growers produce tomatoes alone, experience having proved that it is better practice to follow a definite greenhouse rotation, including two or more of the important forcing crops. No definite cropping plan suited to the needs of growers located in the various sections can be given. The rotations here suggested are followed very closely by many growers in the important forcing sections of New York, Pennsylvania, Ohio, Michigan, and elsewhere.

Plan 1

Tomatoes.—Seed sown July 1 to 15. Plants set in houses August 15 to 30. Vines removed December 15 to 30.

Lettuce.—Seed sown November 15 to 30. Plants set in houses December 15 to 31. Crop harvested March 15 to 31.

Cucumbers.—Seed sown February 1 to 15. Plants set in houses April 1 to 15. Vines removed July 1 to 15.

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Plan 2

Tomatoes.—Seed sown July 1 to 15. Plants set in houses August 15 to 30. Vines removed December 15 to 30.

Lettuce.—Seed sown November 15 to 30. Plants set in houses December 15 to 31. Crop harvested March 15 to 31.

Lettuce.—Seed sown February 1 to 28. Plants set in houses March 15 to 31. Crop harvested June 1 to 15.

Plan 3

Lettuce.—Seed sown August 1 to 15. Plants set in houses September 1 to 15. Crop harvested November 15 to 30.

Lettuce.—Seed sown October 15 to 30. Plants set in houses November 15 to 30. Crop harvested February 1 to 28.

Tomatoes.—Seed sown January 1 to 15. Plants set in houses March 1 to 15. Vines removed to make room for following crops when no longer productive.

Plan 3 is sometimes modified by growing fall tomatoes instead of the first crop of lettuce. The dates given are approximate, as crops are usually set over a period of two to three weeks, and the date of harvesting is determined to a certain extent by weather and other conditions. The greenhouse operator is anxious to have a steady supply for his markets and plans the setting of his crops to give him such a supply.

Fall-grown tomatoes do not as a rule yield such heavy crops as those ripening during early spring, when weather conditions, particularly light, are much more favorable.

Greenhouse tomatoes, during the early stages of their growth, do not fully occupy the space in which they are planted. (See fig. 1.) Some growers plant quick-maturing crops, such as radishes, beets for greens, and lettuce, between the tomato rows, removing these before the tomatoes require the space. Conditions are maintained according to the needs of the tomatoes; and although not ideal for cool crops like radishes and lettuce, returns are often sufficient to cover the expense of bringing the tomatoes well toward the producing stage. Each grower should determine for himself which, if any, crop should be used as a companion crop with tomatoes; sometimes it may prove best to dispense with companion crops altogether.

SOILS

Tomatoes are grown on a wide range of soil types. They are successfully produced upon soils varying from heavy clays to light sands. Light soils are easier to work and ordinarily bring the crop into bearing somewhat sooner than do heavier soils. When the crop is grown on benches where soil only a few inches deep is used, it is usually changed each year. This practice permits the choice of a soil of loamy character, made, if possible, of sods from an old pasture the soil of which is rather light clay loam or a heavy sandy loam. With this should be mixed about one-fourth of its bulk of well-rotted stable manure, preferably cow manure. By composting these two materials several months before they are required for use, a very satisfactory soil for the forcing of tomatoes is produced.

An excellent soil may be prepared by composting fresh sod soil from an old pasture with one-fourth to one-third its volume of peat or muck. To be suitable for this use, the material must

be from a deposit that has been reclaimed and devoted for a few years to the growing of cultivated crops, such as corn, flax, hay, onions, and cabbage. It should be high in plant food, containing at least 2.5 per cent of nitrogen and 0.5 per cent of both phosphoric acid and potash. Such humus can be obtained in many localities, but the advisability of using it must be determined by its cost. If manure is abundant and cheap there would be little to gain in using the muck.

If the supply of manure is limited, soil, muck, and manure may be used together with excellent results. A compost made of 4 parts of old-pasture sod, 1 part of rotted cow manure, and 1 part of suitable muck will generally give excellent results and should be prepared in the manner usually followed. The mixture of the manure and muck often gives better results than are obtained from the use of the materials separately.

Manure, muck, or any of the composts just mentioned may be used in houses where the soil is not changed and where it is desirable to lighten heavy soils, add organic matter and plant food, or otherwise make the soil more suitable for the production of maximum yields of greenhouse crops. When following such rotations as those suggested on page 7, the application of the organic matter and much of the plant food takes place before planting the other crops included in the rotation, as tomatoes do not require the heavy fertilization essential to both lettuce and cucumbers.

SOIL PREPARATION

Although greenhouse conditions necessitate the following of methods in the preparation of the soil somewhat different from those commonly followed outdoors, the principles are the same. With the large forcing houses now in use it is often possible to employ teams or tractors for the plowing, disking, rolling, and other operations necessary to successful greenhouse-tomato growing. In smaller houses without benches and in those fitted with raised benches handwork is depended upon. The preparation of greenhouse soils is fully discussed in Farmers' Bulletins Nos. 1320, The Production of Cucumbers in Greenhouses, and 1418, Lettuce Growing in Greenhouses.

FERTILIZER AND MULCH

Soils well supplied with organic matter and plant food from such composts as those described on page 8 should require but little additional fertilization for the production of a good crop of greenhouse tomatoes; in fact, when tomatoes follow lettuce and cucumbers which have been heavily manured there is some danger that additional applications of manure may result in excessive vine growth at the expense of the fruit.

Commercial fertilizers containing a high percentage of nitrogen must be used with great caution, as an excess of nitrogen causes excessive vine growth and dropping of the blooms, accompanied by failure to bear satisfactory crops. With plentiful supplies of good manure or good compost but little additional nitrogen is needed as a rule. Phosphoric acid is very necessary to the tomato and may be used in liberal quantities with profitable results. Either bone meal

or superphosphate is generally employed. Potash also is essential to the growth of greenhouse tomatoes and should be applied in the form of sulphate of potash. It is difficult to make definite recommendations as to the quantity of commercial fertilizer that should be applied, as this depends largely upon the past treatment of the soil. When using fresh compost little additional fertilization should be necessary or desirable. With soils that have been heavily cropped, applications of a mixture containing 1 to 2 per cent of nitrogen, 8 per cent of phosphoric acid, and 4 to 6 per cent of potash at the rate of from 10 to 20 pounds to each 1,000 square feet of surface should be sufficient. The grower must be guided by his own conditions in using commercial fertilizer, and if the color and vigor of his greenhouse-tomato crop indicates the need for such plant food it should be applied.

Strawy manure and other substances are sometimes employed as a soil mulch, but experimental work, especially that conducted by H. D. Brown and I. C. Hoffman at the Purdue University Agricultural Experiment Station and later work by Mr. Hoffman at the Ohio Agricultural Experiment Station, shows that mulches of this character usually rob the soil of nitrogen due to the locking up of this material by the cellulose-decomposing bacteria, creating a nitrogen deficiency as far as the tomatoes are concerned. The use of strawy mulches has been found to prevent the setting of the first one or two clusters, and their use is not advised.

VARIETIES AND SEED

The tomato has long been popular as a glasshouse crop in England, where a large number of special small-fruited forcing varieties have been developed. These so-called English varieties are largely grown in greenhouses in the United States, particularly in the eastern section of the country. The English varieties pollinate more easily than the American. Carters Sunrise, Stirling Castle, Comet, Best of All, Carters Duke of York, and Perfection are kinds extensively grown. All of these are characterized by a large number of tomatoes borne in each cluster. The title-page illustration shows a portion of a plant of Carters Sunrise, a sort having particular merit.

American varieties of tomatoes are extensively used for forcing work, especially in the Middle West. Globe, Bonny Best, and Stone are varieties largely grown. Marvel, Marglobe, and Marvelosa are wilt-resistant varieties which are being grown where wilt is troublesome.

The market demand influences the choice of type and variety for forcing work, as some sections prefer the smaller English type and other regions demand the larger American type. Work carried on at the Arlington Experiment Farm, Rosslyn, Va., showed no great difference in the yielding qualities of the English and the American tomatoes. Table 2 gives the results obtained with several of these.

In this test the American large-fruited varieties gave a greater total yield and a larger yield per plant than most of the English varieties. Both Earliana and Burbank bore heavy crops of large irregular tomatoes. Of the American varieties the Bonny Best and

Globe gave moderate yields of high-class tomatoes. In the autumn and winter of 1918 a similar test was conducted. The results of this are shown in Table 3.

TABLE 2.—*Comparative yields of different varieties of tomatoes grown in the greenhouses at the Arlington Experiment Farm, Rosslyn, Va., August 17, 1917, to January 31, 1918*

Variety	Number of plants	Weight of tomatoes (pounds)		Variety	Number of plants	Weight of tomatoes (pounds)	
		Total	Per plant			Total	Per plant
Earliana	30	150.53	5.02	Carters Perfection	30	80.69	2.69
Burbank	30	141.82	4.72	Carters Comet	30	79.28	2.64
Bonny Best	30	86.92	2.90	Listers Perfection	30	60.21	2.01
Globe	30	80.94	2.70	Tresco	30	103.96	3.46
Ponderosa	30	115.47	3.85	Carters Duke of York	30	68.92	2.30
Carters Sunrise	30	106.25	3.54	Livingstons Comet	30	64.91	2.16

TABLE 3.—*Comparative yields of different varieties of tomatoes grown in the greenhouses at the Arlington Experiment Farm, Rosslyn, Va., August 25, 1918, to January 7, 1919*

Variety	Number of plants	Weight of tomatoes			
		Total		Per plant	
		Pounds	Ounces	Pounds	Ounces
Globe	31	130	9	4	3½
Dwarf Champion	32	116	11	3	10½
Tresco	32	182	2	5	11
Stirling Castle	29	174	4	6	0
Listers Perfection	29	163	14	5	10½
Carters Comet	32	145	13	4	9
Duke of York	29	137	13	4	12
Comet (B)	32	131	4	4	1½
Carters Sunrise	24	127	13	5	5
Carters Perfection	32	119	5	3	11½

The yields, especially those from some of the English varieties, were very good for a fall crop, lower yields being usually obtained from fall-grown greenhouse tomatoes than from the spring crop.

Seed of two varieties, Carters Sunrise and Stirling Castle, saved from selected plants grown in the greenhouse at the Arlington Experiment Farm, was used in 1920 for the production of a spring crop in the same house used for the previous work. The results of this test are given in Table 4.

TABLE 4.—*Comparative yields of two varieties of English forcing tomatoes grown in the greenhouses at the Arlington Experiment Farm, Rosslyn, Va.*

[Seed sown February 9; plants set in house March 25; first ripe tomatoes June 23; last, August 13, 1920]

Variety	Number of plants	Weight of tomatoes			
		Total		Per plant	
		Pounds	Ounces	Pounds	Ounces
Carters Sunrise	47	450	7	9	9
Stirling Castle	46	419	7	9	1

The data in these tables are presented to show what occurred under the conditions found in the houses where this work was conducted. Globe and Bonny Best seemed to be the best all-round large varieties tested. Carters Sunrise, Stirling Castle, and Comet were apparently the best of the English forcing sorts.

Many growers of greenhouse tomatoes maintain their own seed stocks, and in some cases these are as distinctive as the named commercial varieties. The greenhouse tomato readily lends itself to improvement by selection and crossing, and some growers pay considerable attention to building up and maintaining strains suited to their needs. The Irondequoit (N. Y.) greenhouse men have a select strain of an English forcing tomato which is maintained from year to year, the seed of which may be grown in the greenhouse or in the open. A large number of plants can be produced from a small quantity of seed, and the use of good seed of a variety and strain suited to the purpose to which it is to be devoted is recommended.

STARTING AND GROWING PLANTS

Tomato growers usually grow their own plants. The practice gives them the assurance of a supply of stocky, vigorous plants of the variety and strain desired and makes it possible to set the plants in the houses without the risk of shock and injury incident to shipping. By growing and handling his own plants the grower is able to reduce the danger of introducing diseases, such as Fusarium wilt,[1] and nematodes.[2]

In producing tomato plants the methods followed are determined to a great extent by the season of the year during which the crop is to be grown. Plants for the fall crop are often produced outdoors in a place where they can receive the necessary attention. Coldframes or hotbeds without heat are often used. The greenhouse is usually too hot during July and August for the production of good plants. For the spring crop most growers utilize a separate house where the tomato plants can be protected from cold and given the best of care.

QUANTITY OF SEED AND NUMBER OF PLANTS REQUIRED

There are over 8,000 tomato seeds to the ounce, and a very small quantity of good seed is needed to start plants for a large area. It is always best to use sufficient seed to give an abundance of seedlings. In practice, seed of high vitality should give 2,000 to 3,000 first-class plants per ounce. It is a wise insurance to provide twice the number of plants needed to set the space to be devoted to the crop. Table 5 shows the actual number of plants needed to plant each 1,000 square feet of bed when spaced at varying distances.

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[1] The wilt is due to the attacks at all stages of the development of the plant of *Fusarium lycopersici* Sacc.

[2] The gall-like swellings on the roots are caused by the attacks of an eelworm, *Heterodera marioni* (Cornu) Goodey (*H. radicicola* (Greef) Mueller).

TABLE 5.—*Tomato plants required to set each 1,000 square feet of bed when spaced at varying distances*

Distance between rows	Distance between plants in the row	Plants for each 1,000 square feet of bed space [1]	Distance between rows	Distance between plants in the row	Plants for each 1,000 square feet of bed space [1]
	Ft. in.	*Number*		*Ft. in.*	*Number*
2 feet	2 0	250	3 feet 9 inches	1 6	178
2 feet 6 inches	2 0	200	3 feet 9 inches	1 9	153
2 feet 9 inches	1 6	242	3 feet 9 inches	2 0	133
3 feet	1 3	267	4 feet	1 0	250
3 feet	1 6	222	4 feet	1 3	200
3 feet	1 9	190	4 feet	1 6	167
3 feet	2 0	167	4 feet	1 9	143
3 feet 3 inches	1 3	246	4 feet	2 0	125
3 feet 3 inches	1 6	205	4 feet 3 inches	1 0	235
3 feet 3 inches	1 9	176	4 feet 3 inches	1 3	188
3 feet 3 inches	2 0	154	4 feet 3 inches	1 6	157
3 feet 6 inches	1 3	229	4 feet 3 inches	1 9	134
3 feet 6 inches	1 6	190	4 feet 6 inches	1 0	222
3 feet 6 inches	1 9	163	4 feet 6 inches	1 3	178
3 feet 6 inches	2 0	143	4 feet 6 inches	1 6	148
3 feet 9 inches	1 3	213			

[1] The outside rows of plants are figured as occupying the edge of the area. Adjacent areas of equal size would require slightly fewer plants.

SOIL FOR TOMATO SEEDLINGS

A soil of a friable character well supplied with organic matter is especially adapted to the production of tomato plants. When loam soils of the proper character are not available for the preparation of composts for the starting and growing of the plants, satisfactory results may be secured with other types provided they are modified through the use of muck, manure, sand, or in the case of light sands heavier soils to bring them to the proper physical, moisture-retaining, and plant-food-bearing condition. A compost made of 3 to 4 parts of bluegrass sod and 1 part of cattle manure is excellent. Such a compost should be prepared several months in advance of the time it will be needed and turned two or three times to insure a perfect mixture. It should be sufficiently decayed so that practically all the grass roots and vegetable matter in the manure have disappeared. At the final turning it should be screened to remove stones, lumps, or fibrous matter, and it is an excellent plan to add 2 to 4 pounds of ground bone to each ton of the compost.

STERILIZING THE SOIL

Owing to the general prevalence of diseases caused by Rhizoctonia and other damping-off fungi, which are liable to attack seedlings, it is usually best to sterilize the soil. Sterilization can be effected by spreading the soil 6 to 8 inches deep on a concrete floor and wetting it with a solution of formaldehyde, 1 part of formalin (40 per cent formaldehyde) to 99 parts of water, using a gallon of the mixture to each square foot of soil. Sterilization by steam can be effected by spreading the soil in the greenhouse or on a floor and using the inverted steam pan, as described in Farmers' Bulletin 1320, The Production of Cucumbers in Greenhouses. Another method consists in placing the soil in the flats to be used for growing the seedlings and putting these in a wooden or concrete cabinet fitted

with pipes for the admission of live steam. The steam is turned on and the soil heated to about 212° F., this being accomplished as a rule in 30 to 45 minutes. The flats must be allowed to stand until sufficiently dry to permit handling the soil before the sowing is done.

SEED SOWING AND GERMINATION

The seed is usually sown in drills 2 to 3 inches apart. A convenient method for making the rows consists in pressing the edge of a plastering lath into the well-fined seed bed to a depth of half an inch, repeating the operation for adjoining rows. The seed should be uniformly distributed in these drills at the rate of about four to each inch and covered by filling the furrows with loose loam, leaf mold, muck, or a mixture of sand and soil. Whatever material is used, it should be of a friable character, so that the seedlings can come through the surface without difficulty. It is desirable that the soil be kept in an ideal moisture condition. If it is too wet the seed may rot, and if too dry the seed will not germinate satisfactorily. It is often advisable to cover the bed with burlap until the seeds germinate, but when this is done care must be exercised to remove the burlap by the time the seedlings begin to come up. Temperatures ranging from 70° to 75° F. are satisfactory for the germination of tomato seed. After the seedlings are well up this may be reduced somewhat. Moderately low temperatures are favorable to the securing of stocky plants.

TRANSPLANTING

Tomato plants for the greenhouse crop are usually transplanted once, sometimes twice, before they are set where the crop is to be grown. The seedlings are ready for transplanting in from 10 days to 2 weeks after the seed is sown. They are sometimes moved to flats, where they are set from 2½ to 3½ inches apart and left there until moved into the house where the crop is to be grown. In other cases they are transplanted to paper pots or thumb pots and later shifted to larger pots, plant bands, or berry baskets. The farther the plants can be carried in the plant house without stunting them or allowing them to become rootbound or overcrowded and spindling, the less time will be required for securing the crop in the greenhouse. From 4 to 8 weeks are usually allowed for the production of the plants.

Outdoor-grown plants for the fall crop may be subject to unfavorable temperature conditions. Excessively high temperatures can be partly overcome by shading the plant bed. Greenhouse-grown plants for the winter or spring crop are usually grown in a special house or in a part of one of the main houses. After the plants are up, a day temperature of 60° to 70° F. with a night temperature some 5 to 10 degrees lower is usually satisfactory. Good strong plants are essential to securing profitable yields of high quality.

ESTABLISHING THE CROP IN GREENHOUSES

Plants for the fall crop are usually set during August or early in September. Many of the larger growers in the northern Ohio district aim to plant about August 15; and it is seldom desirable to

defer fall planting much after September 1, as by so doing the crop comes into bearing during the shortest days of the year, when a minimum amount of light is available.

March 1 is a favorite date for setting the plants for the spring crop, but the time varies to suit conditions. It is not desirable to set the plants until the coldest weather is over, as large quantities of fuel would be required to maintain the interior of the houses at a temperature suitable for satisfactory growth. Neither is it desirable to defer planting until the product would mature at a time when low-priced outdoor-grown tomatoes are available on the markets. Plants set about March 1 usually begin to produce ripe tomatoes late in May or early in June. Soil, temperature, weather, variety, cultivation, and many other factors affect the time of ripening.

PLANTING DISTANCES

The width of the beds, type of house, and system of training to be followed must be taken into account in determining the planting distances. There is little to be gained by too close spacing, as this results in excessive shading and in lowered yields per plant. Most of the large growers set the plants in rows 3 to 4½ feet apart with the plants from 12 to 18 inches apart in the rows, although all the planting distances given in Table 5 are used. Varieties having a small habit of growth may be placed closer together than those inclined to make a heavy growth.

SETTING THE PLANTS

The soil should be given a final surface working just before the plants are set. The beds are usually laid off with a marker or with a garden line. Furrows about 6 inches deep are often made with a light tractor or with a horse-drawn plow. When the plants are being set such distances as would make possible the practice of cultivation in both directions it is very necessary that they be accurately "checked," so that the rows will be straight. This is usually done by using cross lines or in large houses by marking the ground in both directions.

Planting follows the usual practices adapted to this class of plants. Those grown in flats are cut apart, leaving as large a ball of soil and roots as possible on each plant, and set in position with the earth firmly packed about them. Plants grown in paper or wooden bands, berry boxes, or other containers are handled in much the same way. It is desirable that the bands or berry boxes be removed when setting the plants, but with such care as to leave the root systems intact. The freshly set plants are always watered, and if planted at a season when the sun is hot they should be moderately shaded for a few days.

CULTIVATION

When proper preparation of the soil has been made, cultivation is limited to maintaining a surface mulch and the resultant control of weeds. Deep cultivation is undesirable and likely to be injurious to the root systems of the plants. Hand tools, such as the hoe, scuffle

hoe, and rake, are employed. Horse-drawn tools are not largely used for the cultivation of greenhouse tomatoes. Some growers mulch the ground between the plants, using fine strawy manure, and give no cultivation after the mulch is applied.

PRUNING AND TRAINING

The single-stem system of pruning and training is almost universally followed, although some growers train the vines to two and sometimes three stems. As the plants grow, the shoots arising between the leaves and the main stem are removed, so that the energy of the plant is thrown into the main stem. Pruning is usually continued until the plant reaches the top of its support as a single stem, after which it is limited to the removal of shoots appearing on the main stalk and in the top of the plant, which usually tend to droop downward. Unless the plants are kept well pruned the foliage will interfere with the admission of sunlight. Some growers make a practice of removing about half of each leaf borne on the lower part of the plant, in order that the light and air will have better access to the plants.

Great caution must be exercised in pruning to avoid spreading such diseases as bacterial canker[3] and mosaic (pp. 24, 25) both of which may readily be transmitted from plant to plant by the pruning knife or by the hands. In pruning, it is better to break off the side shoots with the hands than to prune with a knife or pinch them off with the thumbnail, since in the latter cases the knife or hand is drawn directly across the wounded surface of the stem. Plants showing suspected symptoms of mosaic or canker should be marked and trimmed after the other plants have been pruned, in order to avoid spreading these diseases. When a knife is used, one of the most effective methods of preventing their spread is to sterilize the knife and the hands in a 1 to 1,000 solution of corrosive sublimate after handling each suspected plant.

One method of supporting the plant consists in running a heavy twine from a small stake driven into the ground near the base of the plant or from a coil-wire anchor twisted into the soil in the same location to an overhead attachment, such as a wire or rod secured to the frame of the greenhouse. (Fig. 4.) The plant and the string are gently twisted together as growth proceeds, and an occasional tying of the main stem of the plant to the string with soft twine or raffia is sufficient to give proper support. Figure 5 shows the interior of a house planted to tomatoes trained to a single stem and supported by stakes. These stakes or laths, about half an inch thick and an inch wide, are set in the ground near the plant and tied to overhead wires or other supports. The plants are usually pruned to a single stem and tied every few inches to the stakes with a very soft twine or raffia. The best practice is to tie the string or raffia loosely around the plant just below a fruit cluster or a leaf and tightly to the stake. This method of tying the plants allows the stems to increase in size without being cut by the string, yet supports them when the weight of the tomatoes tends to pull them down. (Fig. 6.) Still another method of training is illustrated in figure 3. Horizontal wires borne by posts

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[3] Caused by *Aplanobacter michiganese* (E. F. Smith) E. F. Smith (*Phytomonas michiganensis* (E. F. Smith) Bergey et al.).

or stakes are used as supports for the plants, the main stem being loosely tied to each wire.

Some growers use a heavy wire attached to screw eyes set in the gutters of the house or to holes drilled in the angle-iron eaves plate of the house. In some cases a woven-wire device consisting of two parallel wires connected by diagonal wire is used, the whole being about an inch wide. The support for the strings and stakes must be strong and tight to prevent sagging. The weight of a house of tomatoes in crop is considerable, and the house must be so constructed that it will support it. In case the greenhouse is not so designed that it can be safely used as attachment for the wires supporting the plants, it is advisable to install anchor posts of pipes or of angle-iron construction to serve this purpose. Such anchors may be placed at the ends of the houses and spaced as much as 100 feet apart, provided they are substantially constructed.

FIGURE 4.—Tomato plants trained to strings.

TEMPERATURE AND VENTILATION

Day temperatures ranging from 70° F. on dark days to 85° on bright ones are satisfactory for tomatoes. Night temperatures of 60° to 65° are usually maintained. Sudden fluctuations as well as excessively low or abnormally high temperatures are extremely injurious to the crop. Success in the growing of greenhouse tomatoes requires the employment of houses capable of being maintained at the proper temperature even under the most unfavorable weather conditions.

Ventilation of the greenhouse-tomato crop is extremely important. The plants must be supplied with some fresh air even in very cold weather, and this must be accomplished without exposing them to drafts. Houses that have ventilators several feet above the plants

and enclose a large volume of air come nearest to meeting the requirements.

POLLINATION

Artificial pollination of greenhouse tomatoes is extremely important. Work carried on by the Oregon Agricultural Experiment Station and reported in their Circular 55 showed that both yields and earliness may be increased through the practice of artificial pollination.

Three methods are available for doing the work. The first and simplest merely involves the shaking of the plants during the middle of the day when the air in the greenhouse is most likely to be dry. By tapping the supports bearing the plants the pollen is dislodged and may come in contact with the stigma of each bloom.

FIGURE 5.—Tomato plants trained to stakes.

According to the second method the pollen is collected on a spoon or a watch glass held under each blossom while the flower is gently jarred with the handle of a camel's-hair brush or some other light object. The spoon is then lifted slightly, causing the pollen to come in contact with the stigma. This method has certain disadvantages, but it is more effective than jarring.

The emasculation method has been found to be more successful than either of the others. In emasculating the tomato flower the petals are pulled off. This also removes the stamens, leaving nothing but the female portion of the bloom. The removal of the stamens and petals of the flower makes it easier to reach the stigma and insures more certain results. Moreover, the removal of these parts shows clearly that that blossom has been worked on and avoids duplication of the work the next day. The work is done when the flower has begun to close its petals and is beginning to show a faded color. The pollen may be obtained from any flower that has its petals well reflexed, for in this condition the flowers usually discharge pollen freely. It is usually

collected on the ends of the fingers and transferred directly to the receptive stigmas of other flowers from which the petals and stamens have been removed. This method practiced every 2 or 3 days usually insures the pollination of a large proportion of the blooms.

WATERING

The tomato requires an abundance of water, but it must be applied with painstaking care. Most growers use a hose for the application of water, and some employ the subirrigation method, using lines of 3 to 5 inch tile, buried in the soil at close intervals, into which the water is run. This method avoids the objectionable puddling of the surface soil, which frequently follows the application of water by a hose or by flooding. Moreover, the splashing of the stems and lower leaves is liable to spread the cladosporium fungus, which causes leaf mold. Overhead irrigation systems seem to interfere with the ripening and distribution of the pollen and are conducive to leaf diseases.

Moderately frequent applications of water, which prevent the soil from drying out too much, are believed to be best. Excessive applications of water and poor ventilation, causing a damp atmosphere, are unfavorable to tomatoes. Careful management of the greenhouse, including the application of water, is essential to success with the crop. It is very important that care be taken to avoid trampling the wet soil. Wide boards laid between the rows for walks prevent this.

FIGURE 6.—A well-trained plant of a special strain of Sunrise, a well-known forcing sort.

INSECT ENEMIES[4]

The commonest forms of insects that injure greenhouse tomatoes are the white fly, plant lice, and the red spider. The greenhouse leaf tyer and the corn earworm may also gain access to the house but ordinarily pass unnoticed, although at times they may cause considerable damage.

[4] Prepared by W. H. White and revised by C. A. Weigel, both of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

WHITE FLY AND PLANT LICE

The presence of the white fly [5] in the greenhouse can be readily detected, as this small white insect usually takes flight when the plants are disturbed. The immature and adult forms develop and feed on the under sides of the leaves and obtain their food by sucking the plant juices. When the insects are abundant this feeding causes the leaves to turn yellow and finally die.

The plant lice, or aphids, which usually attack tomatoes in the greenhouse are the spinach aphid [6] and the potato aphid.[7] These soft-bodied louselike insects feed on the under sides of the leaves and on the terminal shoots by sucking the plant juices. They develop rapidly, and unless they are checked serious damage may result.

CONTROL BY HYDROCYANIC ACID GAS FUMIGATION

The cheapest and most effective method of controlling the white fly and plant lice in the greenhouse is to fumigate with hydrocyanic acid gas. For this purpose calcium cyanide is now used. On exposure to the atmosphere calcium cyanide reacts with the moisture and gives off hydrocyanic acid gas. The gas, being very poisonous, may occasion serious injury to plants or human beings if care is not exercised in its use, although in careful hands and with a little practice this fumigant can be employed with excellent results.

Be cautious in fumigating plants that appear to be more deficient in nitrogen, because such plants are more susceptible to injury than are those with a relatively large soluble-nitrogen content. To insure against the possibility of injury when fumigating with calcium cyanide, it is suggested that water be withheld as much as possible just previous to fumigation. The grower who is interested in hydrocyanic acid gas fumigation may obtain full directions as to its proper use from the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, Washington, D. C.

CONTROL BY NICOTINE FUMIGATION

Fumigation with nicotine is used extensively and with effective results for the control of plant lice; but the white fly is highly resistant and a heavy dosage is necessary to kill even the adults.

Nicotine for fumigation purposes is derived from several sources. The burning of tobacco stems is one of the oldest methods and is largely practiced in sections where the stems are readily obtained. The stems are burned in galvanized buckets or garbage cans, or placed in small heaps along the walks of the house. For even distribution of the material, place the containers or heaps at intervals of about 25 feet along the walks. Before burning, dip the stems in water for a moment and allow them to drain. This will moisten them sufficiently to cause the material to burn slowly without flame and produce a dense, heavy smoke.

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[5] *Trialeurodes vaporariorum* Westw.
[6] *Myzus persicae* Sulz.
[7] *Macrosiphum solanifolii* Ashm.

A more convenient method of fumigating with nicotine is to burn commercially prepared nicotine papers or nicotine fumigating powder.

Liquids containing "free" or volatile nicotine may be vaporized by applying the substance in a thin layer on a hot steam pipe by means of a paint brush or an oil can.

Tobacco stems and the commercial papers, fumigating dusts, and liquids containing volatile nicotine for fumigation contain variable amounts of nicotine, and it is therefore advisable to follow directions for their use as given by the manufacturer. The grower should carefully check results, and if the fumigation has not been effective the quantity of material used should be increased.

RED SPIDER

A small mite, commonly called the red spider,[8] varying in color from light green to red, is one of the most difficult pests to combat. When present in small numbers it feeds on the under sides of the leaves, but as it increases it attacks the entire plant, oftentimes covering it with a fine web. This mite apparently thrives under dry conditions and is usually more abundant on plants that receive but little water on the foliage.

A close watch should be maintained for the first appearance of this pest, in order that it may be checked and not allowed to spread over the entire house. A spray consisting of about 2 pounds of soap and one-eighth pint of nicotine sulfate to 10 gallons of water should be thoroughly applied to the infested plants. During this application every effort should be made actually to cover the body of the mite with the spray. Syringing the plants with a forcible stream of water washes the pests from them, and as many of the mites are unable to return to the plant, this treatment usually results in an effective control. When the plants are in flower, however, such applications may interfere with the proper development and distribution of the pollen and must be employed with caution. Recently sprays (having a 0.0056-percent rotenone content in the final spray) made from either derris extracts or finely ground derris powder have proved very effective in killing the red spider. Growers who are interested in these sprays may obtain further details on their preparation and use from the Bureau of Entomology and Plant Quarantine, Washington, D. C.

GREENHOUSE LEAF TYER

The greenhouse leaf tyer[9] occasionally becomes troublesome on tomatoes in the greenhouse. The moth deposits its eggs in masses on the under side of the leaf. The worms, or larvae, which hatch from these eggs are, when full grown, about three-fourths of an inch long, green in color, and marked with dark longitudinal stripes.

The normal habit of the worms when they are feeding is to fasten the leaves together and feed on the under sides. When abundant they may devour the entire leaf.

If the attack is confined to a few plants, hand picking is the most convenient means of destroying the insect.

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[8] *Tetranychus telarius* L.
[9] *Phlyctaenia rubigalis* Guen.

If the attack is general throughout the house, careful treatments with pyrethrum dust are effective. The pyrethrum dust should be mixed with an equal volume of tobacco dust; hydrated lime may be used, but it is less effective. The treatment consists of making two thorough applications of dust about 20 to 30 minutes apart. The second application is designed to kill the worms that have moved out from the protection of the web where they escaped the first treatment.

Arsenicals are not satisfactory as a control for this pest and are not recommended.

CORN EARWORM

The corn earworm,[10] a common pest on corn, beans, and tomatoes in the field, sometimes develops in the greenhouse and may cause considerable damage in its feeding upon the fruit. Hand picking the worms will usually prove sufficient to hold this pest in check.

DISEASES [11]

Greenhouse tomatoes are subject to a number of diseases, which often materially reduce the crop and result in serious losses. Certain of these diseases are also serious in the field, while others are of importance only under glass, owing to the fact that greenhouse conditions are peculiarly favorable to their development and spread.

DAMPING-OFF [12]

Several fungi are responsible for the damping-off of plants in the seedling stage. The attacks of these fungi are encouraged by crowding in the plant bed, overwatering, too high temperatures, and lack of ventilation. Such conditions also render the seedlings particularly susceptible to infection. Damping-off may be controlled by sterilizing the soil with steam or formaldehyde (see page 13) before the seed is sown. This difficulty may also be effectively prevented by the use of a 6-percent formaldehyde dust, which is mixed with the seed-bed soil just before planting, at the rate of 1½ ounces per square foot of soil. The dust should be worked in to a depth of 2½ to 3 inches. The seed is planted at once, and the soil watered thoroughly after planting. Formaldehyde dust may be purchased or can be prepared by adding 1 pint of commercial formalin (40 percent formaldehyde) to 5¾ pounds of a carrier composed of ground charcoal, sifted leafmold, ground peat, or screened muck. The formaldehyde is thoroughly mixed with the carrier by being stirred or rolled in a tight drum containing a few stones. The dust should be stored in a tight container.

Damping-off may also be effectively controlled by dusting the seed with red oxide of copper. The copper dust is used at the rate of 1 ounce to 10 ounces of seed. The seed and the dust are shaken together in a tight container, and the excess dust is afterward screened off. Seed may also be treated by dipping for 5 minutes in a 1 to 1,200 suspension of Improved Ceresan, and dried without rinsing. This

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[10] *Heliothis obsoleta* Fab.
[11] Prepared by S. P. Doolittle and A. C. Foster, Bureau of Plant Industry.
[12] Caused by *Rhizoctonia solani* Kühn and *Pythium debaryanum* Hesse.

treatment is also of value in controlling certain seed-borne diseases. When treated with Improved Ceresan, seed should not be stored in airtight containers, as it may be injured if stored in this way.

WILT DISEASES

Two diseases, fusarium wilt [13] and verticillium [14] wilt, frequently cause severe losses in the greenhouse. These diseases are caused by fungi which enter the plant through the roots and clog and injure the water-conducting vessels of the stem. While the symptoms of the two diseases vary in detail, both are characterized by a yellowing and wilting of the foliage which begins with the lower leaves and eventually results in the death of the plant. The cut stems of diseased plants show a dark, brownish discoloration between the bark and the pith, and the presence of these diseases is readily determined in this manner. The fungi causing these diseases live and spread in the soil, and the loss is likely to increase each year. They can be effectively controlled, however, by sterilizing the soil and beds with live steam. This is the usual method of control.

A number of varieties resistant to fusarium wilt have been bred which are in general use in many localities. The Marglobe variety, developed by the Bureau of Plant Industry, is widely used as a wilt-resistant tomato, and certain strains of this variety have been developed for greenhouse use. These varieties, however, are not necessarily resistant to verticillium wilt, and soil sterilization is therefore most satisfactory as a means of wilt control.

LEAFMOLD [15]

Leafmold is one of the commonest and most destructive diseases of greenhouse tomatoes. It produces light, yellowish-green spots on the upper surfaces of the leaves, the under surface of such spots is covered by a greenish-olive, velvety growth of the fungus. The disease first attacks the older leaves and works gradually upward, producing severe defoliation. The leafmold fungus causes most damage when the temperature is about 70° F. and the relative humidity about 80 percent. The spores of the fungus do not germinate readily in a dry atmosphere, and the growth of the organism is less rapid under these conditions. The disease is particularly severe on the fall crop in the greenhouse during the latter part of September and early October, when the humidity is likely to be high, especially at night. During these months the ventilators should be kept open day and night to allow outside air currents to enter the houses. Firing from midnight to dawn will also set up air currents and tends to dry the air. This method has proved effective in most seasons, and the additional expense for fuel usually is not excessive. Overwatering should be avoided, and the plants should be watered only in bright weather and in the early part of the day so they will dry off thoroughly before night.

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[13] *Fusarium lycopersici* Sacc.
[14] *Verticillium alboatrum* Reinke and Berth.
[15] Caused by *Cladosporium fulvum* Cke.

A new variety, Globelle, which has recently been developed and introduced by the Ohio Agricultural Experiment Station, is very resistant to leafmold and produces satisfactory crops under conditions that favor the development of this disease on susceptible varieties.

MOSAIC AND STREAK

Mosaic and streak are virus diseases; the infective principle is in the juices of the diseased plants. The common form of tomato mosaic is caused by the same virus as the mosaic of tobacco and is characterized by a green and yellow mottling of the foliage, accompanied by a curling and distortion of the leaves and some stunting of the infected plants. Another less common form of the disease, caused by the virus of cucumber mosaic, makes the leaves extremely threadlike and is often known as "shoestring" or "fernleaf." Ordinary tomato mosaic reduces yields to some extent and occasionally causes noticeable marking of the fruit. The disease is spread by plant lice but more frequently in the pruning, tying, pollinating, and other handling of mosaic-diseased and healthy plants. When once introduced, mosaic is hard to check; every care should be taken to prevent the disease from entering the greenhouses.

These mosaic diseases live over winter on various perennial weeds, especially on nearby groundcherry and pokeberry, and are carried to the cultivated crop by insects. It is therefore essential that all weeds be kept down in the immediate vicinity of the greenhouses. The ordinary tomato mosaic virus also lives for 60 to 90 days in the remains of preceding crops in the soil; hence, if successive crops of tomatoes are grown in the same houses, the soil should be sterilized with steam between crops.

Seedling plants should be grown in separate houses where no older vines are present, and workers who have been handling older plants in other houses should always wash the hands thoroughly with soap and water before working with young plants. The virus of tobacco and tomato mosaic may live in manufactured tobacco, especially that used for chewing, and it has been shown that infection may occur from this source. Its use should be avoided, especially when young plants are being handled.

It must also be realized that after continued brushing against old mosaic plants, the clothes also may carry the virus, and for this reason it is highly important that as few persons as possible work in the house where the seedling plants are growing. Where it is feasible to do so, one man should be assigned to handle the young plants and should avoid working with older plants except when absolutely necessary.

The small plants should be watched carefully, and those that are suspected cases of mosaic should be removed and destroyed, care being taken not to have them touch healthy plants. The hands should always be washed after handling the diseased plants. If mosaic appears soon after transplanting, the plants should be removed. No replants should be made as they usually will develop the disease. After pruning has begun, the removal of plants should be stopped, as the disease is not likely to be checked by this method.

Streak is much more serious in its effects than mosaic and often causes very severe losses. There are several types of streak, the most common and one of the most serious forms being caused by a combined infection with tomato mosaic and certain potato mosaic viruses which are present in nearly all potato plants but produce almost no symptoms on the potato. This form causes a dark-brown streaking of the stem below the growing tip and a brown spotting of the leaflets, which often results in the withering and death of the affected leaves. The plant is severely stunted, and the leaves produced after infection show pronounced mosaic mottling in addition to the brown spotting referred to above. The fruits also develop irregular brown spots that have a somewhat waxy or greasy appearance.

Another common form of streak produces stem and leaf symptoms much like those of the combination form, but the fruits show depressed, brown rings and are often irregular in shape.

Streak is spread in the same manner as mosaic, and the same control methods should be used. It is particularly important, however, not to plant potatoes near the greenhouses, since the potato virus may readily be introduced into them from nearby plants. If plants affected with streak are found in the houses, these plants should be removed at once, great care being taken not to brush them against healthy plants.

BACTERIAL CANKER

Bacterial canker is no longer as common in the greenhouse as it was some years ago, but when it does occur the losses are likely to be very severe. This disease usually progresses upward from the point of infection, and the stem and petioles remain turgid, while the leaflets wither and die. In many cases only one side of the plant is attacked, and the resulting one-sided appearance is very characteristic. In later stages yellowish-white streaks appear on the younger parts of the stems and often crack open to form longitudinal cankers, which give the disease its name. The bacteria attack the tender tissues of the stem, and the pith next to the wood becomes diseased and yellowish brown in color and separates readily from the wood at the point of infection. The disease is easily spread by pruning, and all infected plants should be removed and destroyed. (For precautions in pruning, see p. 16.)

Bacterial canker is seed borne, and new outbreaks usually can be traced to infected seed. In eliminating the disease, it is essential that seed be secured from sources where the disease has not occurred. Seed may be treated with Improved Ceresan, as described on page 22, or may be soaked 5 minutes in a 1 to 3,000 solution of corrosive sublimate (mercury bichloride) and afterwards washed for 10 minutes in running water and dried. A 1 to 3,000 solution of mercury bichloride may be prepared by using the tablets ordinarily sold by druggists and dissolving them in three times as much water as is directed for use in making the usual 1 to 1,000 solution. If canker has occurred in the greenhouses, the soil should be steam-sterilized if it is possible to do so. Fresh or sterilized soil should be used for the seedlings for the next crop, and all flats, benches, and coldframes should be washed with a 1 to 50 solution of formaldehyde.

BLOSSOM-END ROT

Blossom-end rot is a nonparasitic disease, which causes a dry decay of the blossom end of the fruit. The conditions that cause the disease are far more complicated than is usually recognized. Experiments conducted in the greenhouses at Arlington Experiment Farm, Va., indicate that blossom-end rot is caused by either one or several unfavorable environmental conditions that may interfere with the normal growth and development of the plant and fruit. Drought, which interferes with the movement of food materials from the vegetative part of the plant to the fruit, nitrogen starvation, and excessive soil moisture all seriously interfere with normal growth and favor development of blossom-end rot. Liberal and adequate supplies of superphosphate in the soil are essential in maintaining a normal condition of the plant.

Loss from the disease can be materially reduced, but not entirely prevented, by careful regulation of the temperature with respect to outside light conditions, by careful watering, by avoiding the use of heavy applications of nitrogen, especially manure, and by supplying sufficient superphosphate, which is so essential for normal growth of the tomato. The disease is likely to develop on plants when any one of several unfavorable growth conditions appear, especially on plants that have grown for a long period under favorable temperature and soil-moisture-nutrient conditions and then later are exposed to high temperature and drought.

STEM ROT [16]

Stem rot occasionally causes some loss in greenhouse tomatoes and is characterized by a decay of the stem at the soil line. The injured surface becomes covered with a white, moldlike growth, and when the stem is broken open it will usually be found to contain small, irregular, hard, black bodies (sclerotia) which are formed by the fungus. Steam sterilization of the soil is the best method of control.

ROOT KNOT

The attacks of minute eelworms (nematodes)[17] give rise to swollen galls on the roots of tomato plants, causing a yellowing and sometimes premature death of the leaves and a stunting of the plants, with a heavy decrease in yield and sometimes even death. The development of these parasites is greatly retarded by soil temperatures of less than 60° F.

Sterilization of the soil with steam during the summer months is regarded as the most effective control for this disease. It is the only method that will insure complete sterilization, and this is of utmost importance in seed beds since replanting in clean soil is absolutely useless if the seedlings are already infested.

Installation of the buried-tile system is the cheapest and best for use over a long period of time. Tiles laid 12 to 18 inches deep in rows 18 inches apart are very satisfactory. The loose joints are covered with about 6 inches of straw to allow the egress of steam and

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[16] Caused by *Sclerotinia sclerotiorum* (Lib.) Massee.
[17] *Heterodera marioni* (Cornu) Goodey.

to keep the soil from packing in. Steam at a pressure of 25 to 100 pounds should be used. Steaming should continue until the surface soil reaches a temperature of 150° to 160° F. During the process of sterilization the soil should be dry to begin with, loose, and covered with thick canvas or tarpaulin to obtain maximum efficiency.

Temporary and partial sterilization may be obtained by the use of ammonium thiocyanate at the rate of 200 pounds per acre, applied in aqueous solution to insure even distribution. This treatment should be repeated at the end of 2 weeks; then a period of at least 3 months must elapse before planting.

Care should be taken in every case to sterilize all possible sources of reinfestation, such as walks, utensils, equipment, walls, etc. This may be done by washing these things with a 4- to 5-percent formalin solution and closing the house up for several days.

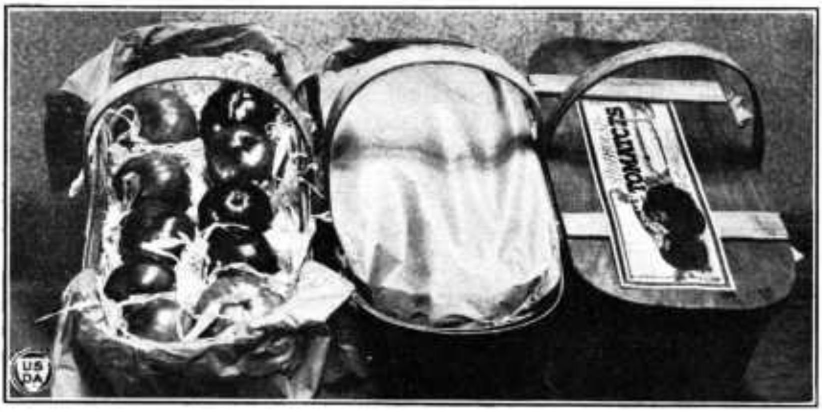

FIGURE 7.—Ten-pound veneer baskets largely used for packing and marketing greenhouse tomatoes.

This same formalin solution may be used for partial sterilization of the beds. It probably is not as effective as ammonium thiocyanate, but the soil may be used within a much shorter time after treatment.

In attempting to reduce the nematode population by means of chemicals, the soil should first be freed as much as practicable of all roots and plants, which should be burned.

Nematode control is one of the most difficult problems the greenhouse tomato grower must meet.

HARVESTING AND HANDLING

Greenhouse tomatoes can usually be left on the plant until ripe and still be placed on the market and in the hands of the consumer in perfect condition. The high quality of a product handled with the dispatch possible with the greenhouse tomato adds materially to its popularity.

Most growers make a practice of gathering the tomatoes two or three times a week. Pickers use a basket or some other suitable container for transferring the product to the packing room, wheelbarrows or trucks running on the concrete walks usually being em-

ployed to expedite the handling of the crop. Most growers grade, sort, and pack according to size, quality, and market demands. The tomatoes are wrapped in tissue paper if they are to be shipped a considerable distance or to accord with market demands. Larger fruited sorts are usually wrapped singly, whereas the small forcing types are often wrapped three or four together.

Many kinds of packages are used. Some growers use a veneer basket, such as is shown in Figure 7, holding 10 pounds of wrapped tomatoes. The standard bushel box is extensively used in the Boston, Mass., area. This box is 17½ inches square and 7$\frac{1}{16}$ inches deep, accommodating eight cardboard packages, each of which holds 6 pounds of tomatoes. The standard 4-quart cup, six of which are packed in a crate, is used by some growers. Corrugated-cardboard boxes holding a few pounds and other kinds of containers are also employed.

Splint baskets and certain other containers used for greenhouse tomatoes are regulated as to size and shape by the standard containers act, and they must conform to its requirements. The grower should be sure that the containers he is using conform to the law and that they are properly stamped. Complete information on this subject may be obtained from the Bureau of Agricultural Economics, United States Department of Agriculture.

YIELDS AND RETURNS

Fall-grown tomatoes seldom yield as heavily as the spring crop, which is produced when growing conditions are more favorable. A yield of 4 pounds per plant is considered good for the fall crop. As much as 10 pounds per plant is sometimes secured in the spring. Tables 2, 3, and 4 (p. 11) show yields obtained with various varieties grown in the greenhouses at the Arlington Experiment Farm. A grower in the Rochester, N. Y., area secured a yield of 5,000 pounds in a greenhouse about 30 by 180 feet. This yield is perhaps higher than could be expected under less favorable conditions.

Gross returns range from as low as 10 cents a pound to as high as 25 cents. The net returns depend on such factors as the amount of the investment in greenhouses and other equipment and the cost of fuel, labor, manure, fertilizer, packages, and other widely varying factors.

The public is rapidly learning to appreciate the superior qualities of greenhouse-grown tomatoes. They are more popular than the other prominent forcing crops, but it requires great skill to produce them.

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